NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPACE SHUTTLE AVIONICS TECHNOLOGY

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SUMMARY

This briefing will cover a short description of the overall requirements being considered, the range of systems approaches under investigation and a summary of the technology and advanced development programs being pursued.

NASA-S-70-3138-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- AVIONICS RELATED REQUIREMENTS
- SYSTEMS APPROACHES
- TECHNOLOGY AND ADVANCED DEVELOPMENT PROGRAMS

PROGRAM REQUIREMENTS

The Space Shuttle avionics must meet the program requirement of low development and operational costs while supporting the mission.

The avionics must operate the booster and orbiter through all mission phases and support rapid checkout and turnaround. The mission phases include launch, orbital operations, reentry, atmospheric flight and landing at dedicated facilities. The system is being required to rendezvous with the planned Space Station/Base and small passive satellites (with assistance from ground based tracking when appropriate).

NASA-S-70-3137-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

PROGRAM REQUIREMENTS

- LOW DEVELOPMENT AND OPERATIONAL COSTS
- SUPPORT MISSION REQUIREMENTS
  - LAUNCH
  - ORBITAL OPERATIONS
    - RENDEZVOUS
      - SPACE STATION/BASE
      - PASSIVE SATELLITES
  - REENTRY
  - ATMOSPHERIC FLIGHT
  - LANDING
  - RAPID TURNAROUND - CHECKOUT

SPACE SHUTTLE AVIONICS - EXISTING TECHNOLOGY

One approach to the avionics systems design being considered relies on existing technology (integrated circuits), off-the-shelf subsystems (or minor modifications) and ground based automated checkout and flight monitoring. Inflight monitoring and support would be provided by Mission Control Center, Houston (MCCH) computer facilities. This systems design provides the capability to fly all required missions. It also contains a high level of redundancy and fault tolerance.

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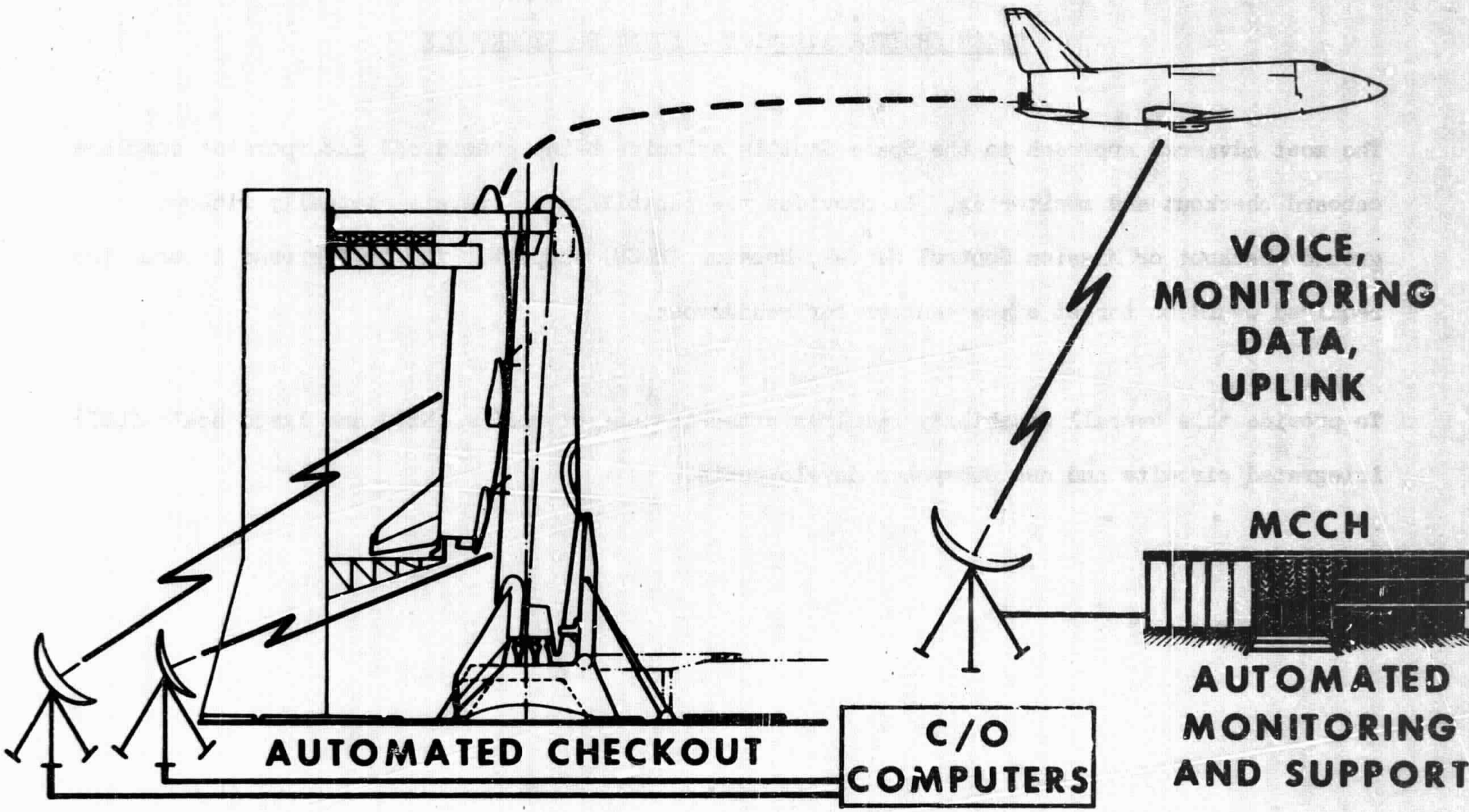
SPACE SHUTTLE AVIONICS



EXISTING TECHNOLOGY - INTEGRATED CIRCUITS, 'OFF-THE-SHELF' SUBSYSTEMS
(747, F15, ETC)

SPACE SHUTTLE AVIONICS - ADVANCED TECHNOLOGY

The most advanced approach to the Space Shuttle avionics being considered incorporates complete onboard checkout and monitoring. It provides the capability to operate virtually without ground checkout or Mission Control Center, Houston (MCCH) support. The only ground information required would be target state vectors for rendezvous.

To provide this overall capability requires extensive use of medium (MSI) and large scale (LSI) integrated circuits and new subsystem developments.

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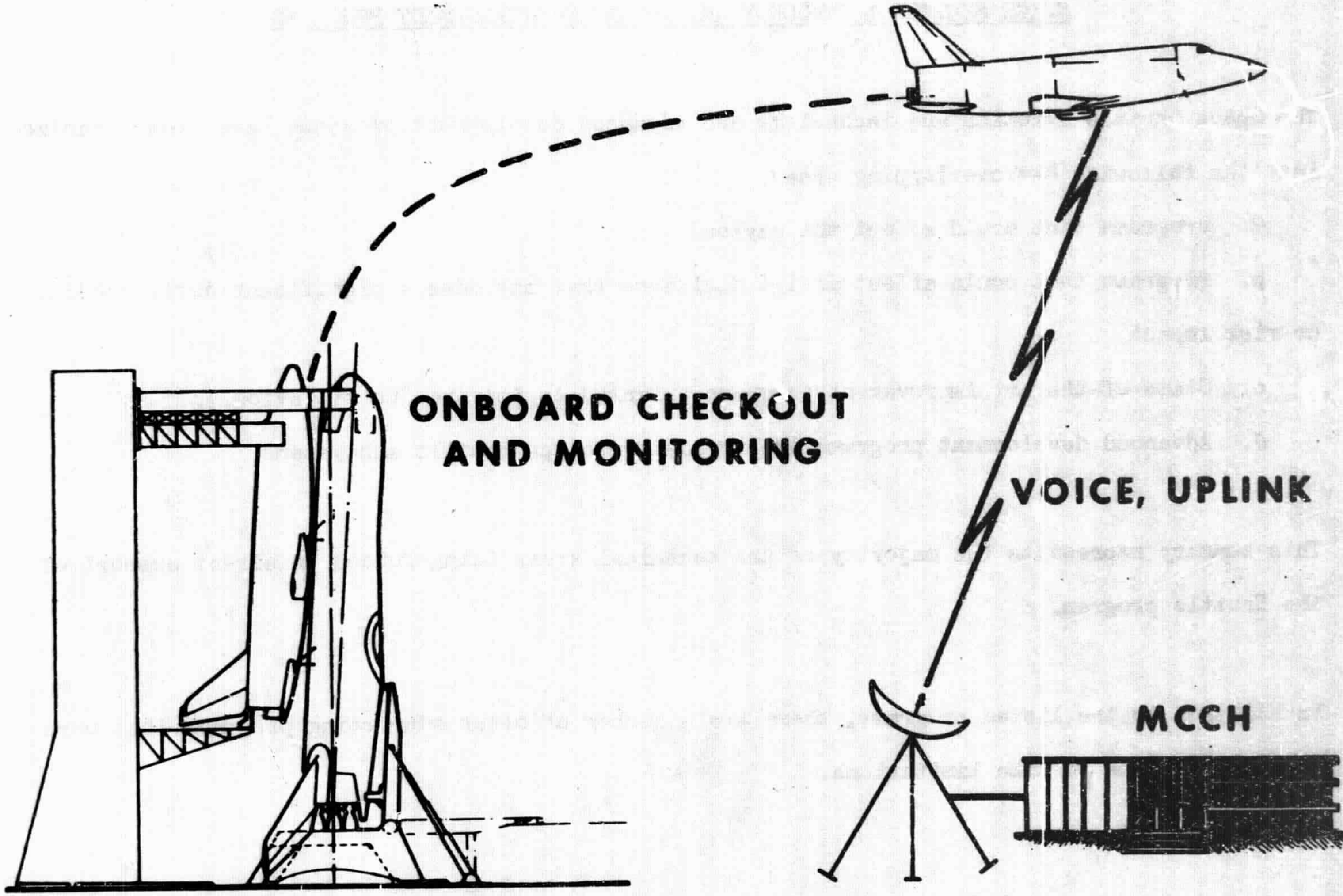
SPACE SHUTTLE AVIONICS



ADVANCED TECHNOLOGY - MSI, LSI CIRCUITS, NEW SUBSYSTEMS

SPACE SHUTTLE TECHNOLOGY AND ADVANCED DEVELOPMENT PROGRAMS

The Space Shuttle avionics and technology and advanced development programs have been organized into the following four overlapping areas:

a. Programs that could affect the payload

b. Programs that could affect design decisions that may have a significant cost, schedule or risk impact

c. State-of-the-art improvement programs oriented to improve Shuttle avionics

d. Advanced development programs to provide prototype Shuttle subsystems

This summary represents the majority of the technical areas being funded in direct support of the Shuttle program.

In addition to the listed programs, there are a number of other supporting programs that were not included due to time limitations.

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SPACE SHUTTLE AVIONICS TECHNOLOGY AND ADVANCED DEVELOPMENT PROGRAMS

- PAYLOAD
  - G, N, & C FOR UNPOWERED LANDING
  - MULTIPLEXED DATA TRANSMISSION
  - POWER DISTRIBUTION AND CONTROL
- COST/SCHEDULE/RISK
  - SYSTEMS TECHNOLOGY
  - CHECKOUT AND MONITORING
  - SOFTWARE/HARDWARE CONSIDERATIONS
  - COMPONENTS TECHNOLOGY
  - INERTIAL SYSTEM CONFIGURATION
  - DISPLAYS AND CONTROLS
  - MASS DATA STORAGE
- STATE-OF-THE-ART IMPROVEMENT PROGRAMS
  - INSTRUMENTATION SENSORS
  - POWER CONDITIONING
  - SECONDARY BATTERIES
- ADVANCED DEVELOPMENT PROGRAMS
  - 5.9 - 6.4 GHz COMMUNICATIONS COMPONENTS
  - H_2/O_2 FUEL CELLS
  - RENDEZVOUS AND DOCKING SENSOR

GUIDANCE, NAVIGATION AND CONTROL FOR UNPOWERED LANDING

Removal of the Space Shuttle orbiter air-breathing engines represents the potential for a large increase in the available payload. To provide the data on vehicle and facility requirements necessary to support an unpowered orbiter, a comprehensive analysis, simulation and test program is being conducted. This will also provide early operational experience to help in the development of strategies for manual and automatic guidance and control and their relationship to each other.

The programs are primarily concerned with subsonic flight from approximately 12 Km altitude through touchdown. The range of programs include:

a. Energy management techniques

b. Guidance and control techniques for approach and landing in the presence of gusts and winds

c. Advanced automatic landing systems which utilize the redundant inertial measurement systems required by other phases of the mission

SPACE SHUTTLE AVIONICS TECHNOLOGY

- G, N & C FOR UNPOWERED LANDING
  - PURPOSE
    - PROVIDE DATA TO HELP ESTABLISH VEHICLE AND FACILITY REQUIREMENTS
    - PROVIDE EARLY OPERATIONAL EXPERIENCE
  - SCOPE
    - FROM 12 KM ALTITUDE TO TOUCHDOWN
    - ANALYSIS
    - SIMULATION
    - FLIGHT TEST

MULTIPLEXED DATA TRANSMISSION

Preliminary analyses have indicated that the space shuttle orbiter mass could be reduced more than 400 Kg if discrete wiring for all signals (data and control) were replaced by a redundant system using multiplexing techniques. Since this approach has not been previously used in critical control systems, a comprehensive program has been instituted to gain experience with various approaches and to develop confidence in their use.

The programs are oriented to data rates between 1,000,000 and 5,000,000 bits per second. A number of different approaches are included with some being carried through breadboard fabrication and evaluation in closed loop control systems simulation.

NASA-S-70-3135-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- **MULTIPLEXED DATA TRANSMISSION**
  - **PURPOSE**
    - DEVELOP CONFIDENCE IN MULTIPLEX TECHNIQUES FOR CRITICAL SYSTEMS
    - PROVIDE DATA ON THE CHARACTERISTICS OF DIFFERENT TECHNIQUES
    - REDUCE VEHICLE WEIGHT (POTENTIAL OF OVER 400 KG)
  - **SCOPE**
    - DATA RATES OF 1 - 5 MHz
    - SEVERAL DIFFERENT APPROACHES
    - DESIGN ANALYSIS AND TRADEOFF STUDIES
    - BREADBOARD EVALUATION
    - CLOSED LOOP SIMULATION EVALUATION

POWER DISTRIBUTION AND CONTROL

Preliminary analyses have indicated that the Space Shuttle orbiter mass could be reduced 500 to 1100 Kg if a decentralised power control system (operated by a data bus) were substituted for the conventional approach of cockpit power switching.

To provide the necessary technology, remotely operated, solid state circuit breakers development is being pursued. At the present time, both AC and DC units have progressed to the point where they are competitive with conventional circuit breakers. Continuing work is oriented to reducing the power losses, developing reliability and application data and extending the range of available devices.

The use of flat wire cabling also has the potential for reducing vehicle weight. The majority of the effort in this area is oriented to the development of satisfactory termination and connector designs.

NASA-S-70-3133-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- POWER DISTRIBUTION AND CONTROL
  - PURPOSE
    - PROVIDE THE TECHNOLOGY AND COMPONENTS NECESSARY FOR DISTRIBUTED, REMOTELY OPERATED POWER DISTRIBUTION SYSTEMS
    - REDUCE WEIGHT (POTENTIAL OF 500 - 1100 KG FOR THE ORBITER)
  - SCOPE
    - SOLID STATE AC AND DC CIRCUIT BREAKER DEVELOPMENT
    - FLAT WIRE CABLE DEVELOPMENT

SYSTEMS TECHNOLOGY

The Apollo and aviation programs have demonstrated that the basic technology necessary to fly the Space Shuttle missions is available now. The real challenge is to reduce all costs and utilize the avionics in the most effective manner to increase the payload and improve safety. To meet this challenge, a new level of systems technology is required.

This program will identify the tradeoffs associated with different levels of component technology (for example, integrated circuits, medium scale integration, large scale integration). The development of systems technology will also:

a. Identify the tradeoffs associated with selected systems requirements such as "fail operative-fail operative-fail safe"

b. Identify and develop techniques to meet reliability and redundancy requirements

c. Determine approaches to achieve the use of identical avionics in the booster and the orbiter. This will include appropriate tradeoff data.

d. Identify critical avionics components, subsystems, and interfaces for selected systems designs. This will include the development of program plans to reduce cost and risk in areas which have a potentially significant benefit.

e. Development of criteria for the evaluation of various avionics systems designs

NASA-S-70-3122-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- SYSTEMS TECHNOLOGY
  - PURPOSE
    - — PROVIDE SYSTEMS TECHNOLOGY TO SUPPORT THE AVIONICS CONFIGURATION DEFINITION CONSISTENT WITH
      - LOW DEVELOPMENT COSTS
      - LOW PROCUREMENT COSTS
      - LOW OPERATIONAL COSTS
      - MISSION REQUIREMENTS
  - SCOPE
    - — TECHNOLOGY TRADEOFF STUDIES
    - — SYSTEM REQUIREMENTS TRADEOFFS
    - — TECHNIQUES FOR MEETING RELIABILITY AND REDUNDANCY REQUIREMENTS
    - — APPROACHES TO ACHIEVE BOOSTER-ORBITER COMMONALITY
    - — IDENTIFICATION OF CRITICAL AVIONIC COMPONENTS AND INTERFACES-PLAN PROGRAMS TO REDUCE RISK

CHECKOUT AND MONITORING

The ability to automate vehicle checkout and inflight monitoring will have more impact on the operational costs of the Space Shuttle than any other feature of the avionics. As a result, a substantial effort is being devoted to establishing the technology and experience necessary to automate checkout and monitoring.

The Apollo program owes its success, in part, to the extensive thorough preflight systems check-out and the ability to adequately monitor the inflight systems performance. This has contributed to the small number of inflight failures and the ability to accomodate those that have occurred. To provide these capabilities while automating represents a significant challenge.

The program to develop the experience and technology includes:

a. State-of-the-art surveys

b. Detailed investigations of the techniques necessary for specific subsystem checkout. The major efforts are currently in environmental control systems, guidance and control systems and hydrogen-oxygen rocket engines.

c. Evaluation of an existing breadboard automatic checkout system oriented to the Skylab program

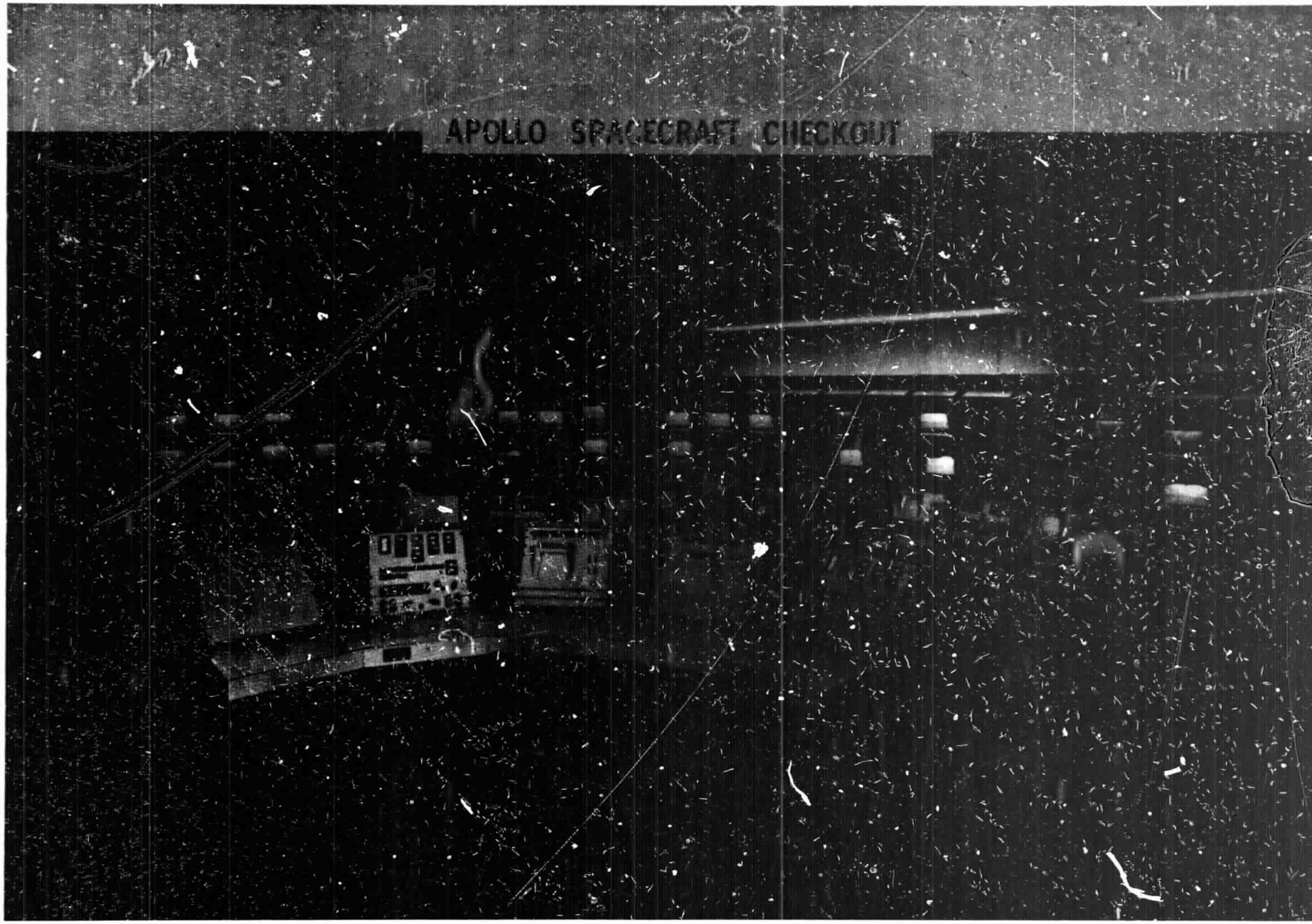
d. Flight testing of an existing system to gain operational experience in a controlled flight environment

SPACE SHUTTLE AVIONICS TECHNOLOGY

- CHECKOUT AND MONITORING
  - PURPOSE
    - DEVELOP THE TECHNOLOGY AND EXPERIENCE NECESSARY TO AUTOMATE CHECKOUT AND MONITORING
  - SCOPE
    - STATE-OF-THE-ART SURVEYS
    - SPECIFIC SUBSYSTEM INVESTIGATIONS
    - BREADBOARD SYSTEM EVALUATION
    - FLIGHT TEST OF AN EXISTING AIRCRAFT SYSTEM

APOLLO SPACECRAFT CHECKOUT

The photograph illustrates the amount of equipment and requirement for individual participation involved in Apollo Command and Service Module (or Lunar Module) checkout and launch preparation.


APOLLO SPACECRAFT CHECKOUT

SOFTWARE/HARDWARE CONSIDERATIONS

An area of significant cost in previous systems development has been the flight software. As a result, programs are being conducted to establish the technology and experience necessary to select and develop a system balanced between hardware and software considerations of cost, weight, power, verification expense, etc.

SPACE SHUTTLE AVIONICS TECHNOLOGY

- SOFTWARE/HARDWARE CONSIDERATIONS
  - PURPOSE
    - ESTABLISH THE TECHNOLOGY AND EXPERIENCE NECESSARY TO SELECT AND DEVELOP A BALANCED SYSTEM
      - HARDWARE COST, WEIGHT, POWER, ETC
      - SOFTWARE DEVELOPMENT, VERIFICATION AND MAINTENANCE COSTS
  - SCOPE
    - LANGUAGE DEVELOPMENT
    - COMPILER INVESTIGATIONS
    - ADVANCED VERIFICATION AND TESTING TECHNIQUES DEVELOPMENT
    - SOFTWARE - HARDWARE TRADEOFF CRITERIA DEVELOPMENT
    - DETAILED EVALUATION OF CANDIDATE CONFIGURATIONS

COMPONENTS TECHNOLOGY

At the present time, the techniques necessary to adequately test and screen large-scale integrated circuits are not adequate. As a result, there is a continuing program to improve the state-of-the-art in these areas.

NASA-S-70-3132-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- COMPONENTS TECHNOLOGY
  - PURPOSE
    - REDUCE THE UNCERTAINTY, COST, AND RISK ASSOCIATED WITH MEDIUM AND LARGE SCALE INTEGRATED CIRCUITS
  - SCOPE
    - PROGRAM TO DEVELOP TESTING AND SCREENING TECHNIQUES TO OBTAIN RELIABLE LARGE SCALE INTEGRATED CIRCUITS

INERTIAL SYSTEM CONFIGURATION

An extensive program is being conducted to provide the data from which the inertial system best suited to the Shuttle requirements can be selected. This includes analysis in addition to laboratory, van, rocket sled and airplane flight test evaluations of system and component prototypes.

For gimbled systems, the main efforts are on developing and evaluating redundancy techniques and testing current production gyroscopes and accelerometers.

For strapdown systems, the main efforts are on testing the following:

a. A system using six single-degree-of-freedom gyroscopes and six accelerometers. This system can tolerate any three gyroscope and any three accelerometer failures.

b. A system using three single-degree-of-freedom gyroscopes used as single axis platforms with three strapdown accelerometers

c. Candidate gyroscopes for either of the above approaches

NASA-S-70-3130-S

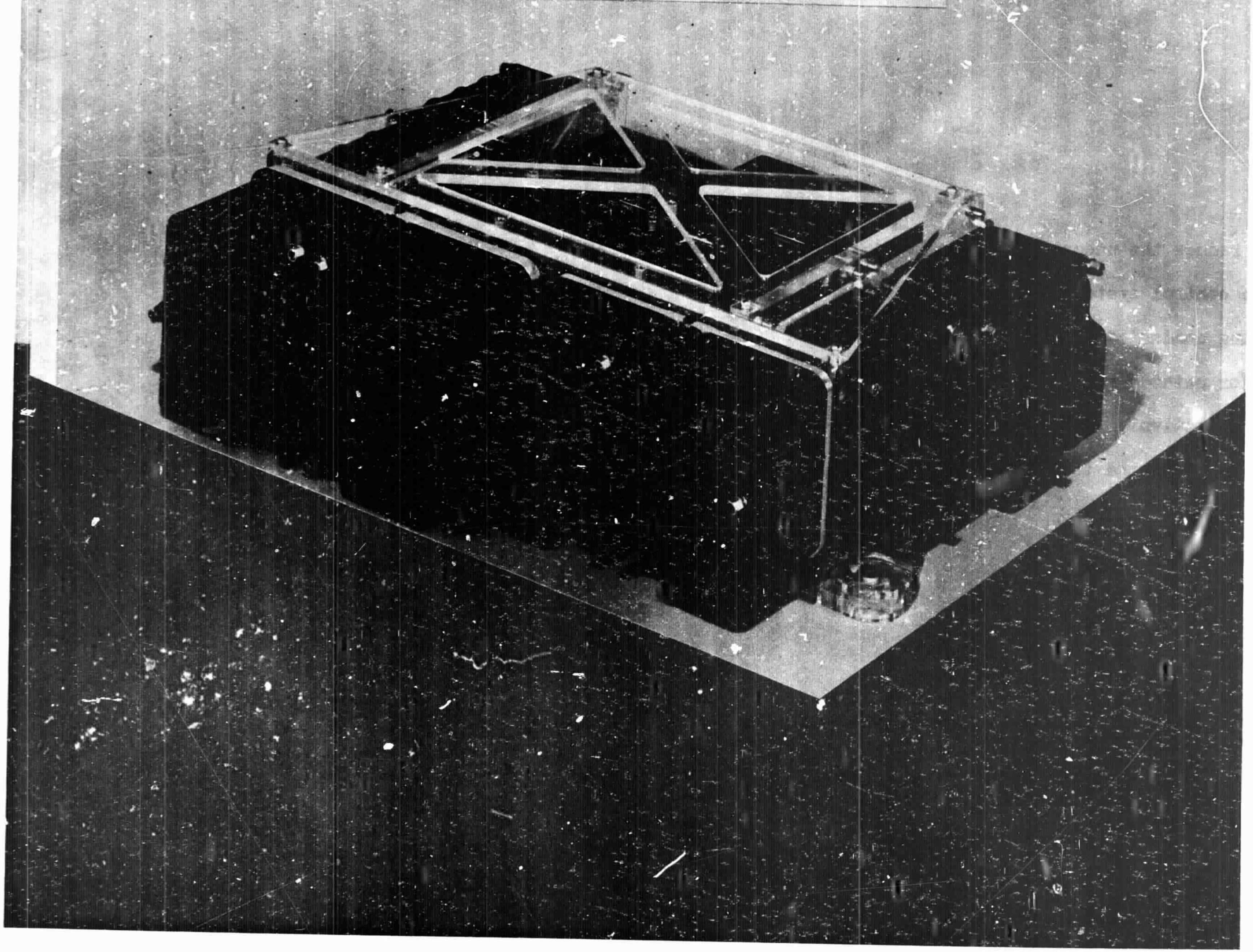
SPACE SHUTTLE AVIONICS TECHNOLOGY

- INERTIAL SYSTEM CONFIGURATION
  - PURPOSE
    - ESTABLISH THE CHARACTERISTICS OF ALTERNATE INERTIAL SYSTEMS PRIOR TO SHUTTLE CONFIGURATION SELECTION
  - SCOPE
    - LABORATORY, VAN, SLED, AND AIRPLANE FLIGHT TEST EVALUATIONS OF SYSTEM AND COMPONENT PROTOTYPES
      - GIMBALED
        - REDUNDANCY TECHNIQUES
        - ACCELEROMETERS, GYROS
      - STRAPDOWN
        - SINGLE DEGREE OF FREEDOM SIX PACK SYSTEM
        - SINGLE AXIS PLATFORM SYSTEM
        - CANDIDATE GYROS

REDUNDANT STRAPDOWN INERTIAL SYSTEM

This photograph shows a high performance strapdown inertial system prototype that is currently under evaluation. This system is completely modularized and provides automatic failure detection and fault isolation. It will provide full inertial reference system capabilities after failure of any three gyroscopes and any three accelerometers.

REDUNDANT STRAPDOWN INERTIAL SYSTEM



DISPLAY AND CONTROLS

To reduce the uncertainty associated with the potential use of an advanced integrated display and control system, a program to develop the technology, components and operating concepts is being conducted. The component improvement being funded is for the development of a flight color cathode ray tube. The major technology effort is in the development of software systems to effectively integrate the flight crew and the avionics. Extensive simulator evaluations are being conducted to establish display requirements and operating concepts.

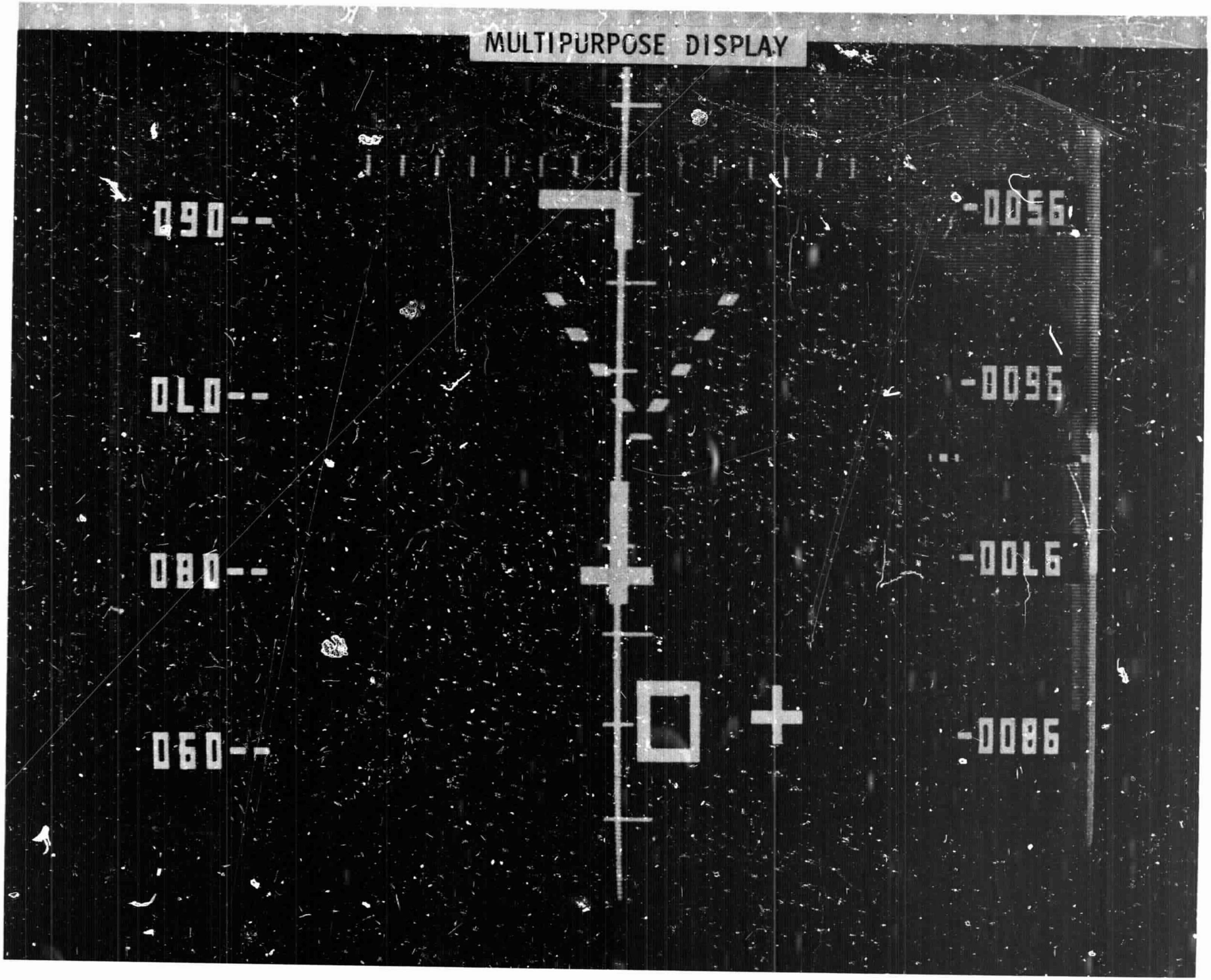
NASA-S-70-3127-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- DISPLAY AND CONTROLS
  - PURPOSE
    - DEVELOP THE TECHNOLOGY, COMPONENTS AND OPERATING CONCEPTS FOR INTEGRATED DISPLAYS AND CONTROLS
  - SCOPE
    - FLIGHT COLOR CRT DEVELOPMENT
    - SOFTWARE SYSTEMS
    - SIMULATOR EVALUATIONS

MULTIPURPOSE DISPLAY

This photograph illustrates some of the capability available in a modern multipurpose display. The unit shows some of the types of formats under evaluation for the Shuttle program.



MULTIPURPOSE DISPLAY
090--
0L0--
080--
060--
-0056
-0096
-00L6
-0086

MASS STORAGE

To provide trade data and the basis for initiating early development (if required) an in-depth evaluation of the state-of-the-art in mass data storage is being conducted.

NASA-S-70-3128-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- MASS DATA STORAGE
  - PURPOSE
    - PROVIDE DATA TO SUPPORT CONFIGURATION TRADE STUDIES
  - SCOPE
    - EVALUATION OF THE PROJECTED STATE-OF-THE-ART AND EXISTING TECHNOLOGIES FOR 10^7, 10^8, AND 10^9 BITS OF BULK STORAGE

INSTRUMENTATION SENSORS

A substantial portion of the continuing NASA program to improve instrumentation sensors is being directed specifically to the Shuttle orbiter and booster requirements. The areas of emphasis are listed on the facing page.

NASA-S-70-3120-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- INSTRUMENTATION SENSORS
  - PURPOSE

    IMPROVE THE STATE-OF-THE-ART FOR SHUTTLE SENSOR REQUIREMENTS
  - SCOPE
    - DIGITAL SENSORS
    - AIR DATA SENSORS
    - CRYOGENIC FUEL QUANTITY GAGING
    - WIDE RANGE TEMPERATURE SENSORS
    - HEAT FLUX SENSORS
    - CRYOGENIC FLOW MEASUREMENTS

POWER CONDITIONING

The NASA conducts continuing programs to improve the state-of-the-art in designs and components for inverters, regulators and DC-DC converters. The purpose and scope of the programs that are of potential benefit to the Shuttle are shown on the facing page.

NASA-S-70-3121-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- POWER CONDITIONING
  - PURPOSE
    - DESIGN AND DEVELOP IMPROVED POWER CONVERTERS
      - HIGHER EFFICIENCY
      - LOWER WEIGHT
      - IMPROVED RELIABILITY
  - SCOPE
    - COMPONENT IMPROVEMENT PROGRAMS
      - CAPACITORS
      - POWER TRANSISTORS
    - DESIGN AND DEVELOPMENT
      - INVERTERS
      - REGULATORS
      - DC - DC CONVERTERS
    - HIGHER VOLTAGE AND WIDER TEMPERATURE (-55°C TO 300°C) RANGE OPERATION

5.9-6.4 GHz COMMUNICATIONS COMPONENTS

On the assumption that the Space Shuttle communications system will be required to operate with Intelsat IV, development of a parametric amplifier and a 100 watt TWT has been initiated. Both programs represent developments from similar items at lower frequencies.

SPACE SHUTTLE AVIONICS TECHNOLOGY

- 5.9 - 6.4 GHz COMMUNICATIONS COMPONENTS
  - PURPOSE
    - INITIATE DEVELOPMENT OF LONG LEAD COMPONENTS TO OPERATE WITH INTELSTAT IV
  - SCOPE
    - DEVELOPMENT AND LIFE TEST OF A 100 WATT TWT
    - DEVELOPMENT AND TEST OF A FLIGHT PROTOTYPE PARAMETRIC AMPLIFIER (LESS THAN 2 dB NOISE)

H_2O_2 FUEL CELLS

The NASA is conducting an extensive program to improve H_2O_2 fuel cells. The effort includes technology programs to improve the state-of-the-art, test and evaluation programs of the most advanced existing systems and the development of two competitive engineering models for the Shuttle application. The design goals for the Shuttle engineering models are:

a. More than 5000 hours life

b. The ability to supply five kilowatts continuous power and ten kilowatts peaks power

c. A total mass in the range of 18-27 Kg/KW.

NASA-S-70-3123-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- H_2 O_2 FUEL CELLS
  - PURPOSE
    - – IMPROVE FUEL CELL CAPABILITY
      - LONGER LIFE
      - LOWER WEIGHT
      - BETTER LOAD TOLERANCE
      - PROPULSION GRADE H_2/O_2
      - LOWER TEMPERATURE OPERATION
  - SCOPE
    - – SINGLE CELL MATRIX DEVELOPMENT
    - – TESTING OF MOL LOW TEMPERATURE MATRIX FUEL CELL
    - – ADVANCED MOL STACK DEVELOPMENT AND DEMONSTRATION
    - – FABRICATION AND TEST OF ENGINEERING MODEL SHUTTLE DESIGNS - 5 KW, 18-27 KG/KW

SECONDARY BATTERIES

At the present time, long life high energy density secondary batteries are not available. As a potential operating cost reduction, the NASA is conducting a program to improve the state-of-the-art in the silver-zink flight batteries. It is oriented primarily to increasing the life through materials, detailed design and fabrication techniques improvement.

NASA-S-70-3119-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- SECONDARY BATTERIES
  - PURPOSE
    - DEVELOP ON IMPROVED Ag - Zn BATTERY
  - SCOPE
    - MATERIALS
    - DETAILED DESIGN
    - FABRICATION TECHNIQUES

<u>RENDEZVOUS AND DOCKING SENSOR</u>

To fully evaluate the potential of rendezvous and docking systems using lasers for target illumination, an existing program is being modified to provide a Shuttle system. This program currently uses a gallium arsenide laser for an illuminator and an image dissector tube as a detector. If initial design vehicle tradeoff studies are satisfactory, this program may be carried through development and qualification.

NASA-S-70-3118-S

SPACE SHUTTLE AVIONICS TECHNOLOGY

- RENDEZVOUS AND DOCKING SENSOR
  - PURPOSE
    - DEVELOP A FLIGHT PROTOTYPE LASER RENDEZVOUS AND DOCKING SYSTEM
  - SCOPE
    - DESIGN - ADAPTATION OF AN EXISTING PROGRAM
      - Ga As LASER
      - IMAGE DISSECTOR
    - DEVELOPMENT
    - LABORATORY AND QUALIFICATION TESTING